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WEBB INSTITUTE

February 11, 2016

Office of Naval Research

To Whom It May Concern:

SUBJECT: FINAL REPORTS

Enclose, please find the required final reports for ONR Grant N00014-10-1-0773 entitled "Equipment for Ship Testing Facilities for the FY10 Congressional Add Entitled: (C) SHIP MODEL TESTING."

Please contact me with any questions or concerns relating to this submittal.

Sincerely

Richard A. Royce

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14. ABSTRACT
This proposal identifies numerous projects that have improved the research and educational capabilities of Webb Institute. The purchases identified either replace obsolete equipment, improve the fidelity of the existing equipment, and implement new research at Webb. The projects include particle image velocimetry, improved wave-making, alternative fuel power and emissions analysis, filtered electric power, and structural analysis equipment. The projects covered by this grant enable Webb to conduct research and educational opportunites on the forefront of technology. This project was initially sponsored by Congressman Peter King (NY-02) and subsequently by Congressman Steve Israel (NY-03).

15. SUBJECT TERMS
Towing tank equipment, wave-maker, power filter, circulating flow channel, particle image velocimetry, emissions gas analyzer, dual fuel, material tester, universal tester, laser scanner and 3D printer

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Award Information

Award Number	N00014-10-1-0773
Title of Research	Equipment for Ship Testing Facilities for the FY10 Congressional
Principal Investigator	Richard A. Royce, Ph.D.
Organization	Webb Institute

Technical Section

Technical Objectives

This grant provides funding for the improvement of ship testing equipment/facilities at Webb Institute. Webb Institute is the oldest college of Naval Architecture and Marine Engineering in the United States and the only college devoted solely to the study of these disciplines. Since its founding in the late 1800s Webb has been a self-sustained college and has no prior government funding to support maintenance or enhancement of its infrastructure. This grant allows Webb to undertake a major modernization of its laboratories with state-of-the-art equipment and to continue to produce excellent graduates in our field.

Technical Approach

In order to address our current testing limitations, we propose to modify the towing tank, replace the circulating water channel and enhance our marine engineering laboratory. The list of proposed procurement projects is as follows:

Robinson Model Basin Improvements

- Replace wavemaker with eight-paddle active wave absorption equipment
- Install double rail system
- New multi-degree of freedom dynamometer
- Add particle image velocimetry capabilities
- Update data acquisition equipment to provide increased band width (number of channels) and increased frequency of data capture.
- New wave probes that will provide increased range of linear response.
- New beach to improve the wave damping of transient waves between carriage runs and wave-maker residuals
- New viewing window in the side of the tank to enable PIV studies and wetted surface measurement of high speed craft
- New carriages drive system to reduce low-speed carriage vibrations and increase the high-speed limit for towing.
- Environmental improvements to the towing tank space.
- Raise the sill of the tank by one foot. This will increase the length of "deep-water" waves that can be generated and will permit higher amplitude waves to be generated.

Other

- Replace circulating water channel
- Add emissions testing Equipment
- Clean electrical power to Robinson Model Basin and Haeberle Laboratory

New Additions

- New material testing machine with environmental chamber
- New dual-fuel test bed for Haeberle Laboratory
- Upgrade existing Southwark Emery universal test machine
- 3D printer with ultra-high surface definition

- CFD Workstations

Since the inception of this grant, Webb has requested a number of project re-alignments that are covered under existing funding. Webb was able to secure reduced cost quotes for a number of our projects, and some of the initial projects were dropped in favor of projects deemed to have greater benefit to our research capabilities. Webb has requested and received permission to proceed with the identified re-alignment projects (see New Additions above).

Progress Statement Summary

This grant identifies numerous facilities improvements for Webb Institute. Since the final approval of the grant in July of 2010, Webb has completed work on eighteen of the original nineteen projects. Six new projects were approved in the intervening years on this project. The spending to date accounts for 100% of the total budget. The research associated with the novel energy harvesting device was abandoned (with program manager approval) in favor of purchasing more data acquisition equipment (ie. FARO laser scanner, data telemetry, and velocity profiler).

Table 1: Spending vs. budget comparison

Item No.	Description	Submitted Budget	9/23/2014 Request Budget	6/30/2015 Spending To Date	Comparison
1	Wavemaker	$ 180,000	$ 135,145	$ 137,965	$ (2,820)
2	Carriage/Double Rail System	$ 180,000	$ 65,000	$ 17,569	$ 47,431
3	PMM and MDOF Dynamomete	$ 220,000	$ 28,000	$ 19,531	$ 8,469
4	Particle Image Velocimetry	$ 200,000	$ 210,740	$ 208,910	$ 1,830
5a	Data Acquistion System	$ 20,000	$ 59,553	$ 134,036	$ (74,483)
5b	Wave Probes	$ 40,000	$ 25,000	$ 40,247	$ (15,247)
5c	Adjustable False Bottom	$ 60,000		$ -	
5d	Beach	$ 10,000	$ 1,760	$ 760	$ 1,000
5e	Underwater Viewing Window	$ 10,000	$ 26,126	$ 26,126	$ (0)
5f	Carriage Speed Control	$ 100,000	$ 35,000	$ 9,967	$ 25,033
5g	Tank Environmental	$ 100,000	$ 20,236	$ 7,736	$ 12,500
5h	Raise Sill	$ 100,000	$ 14,300	$ 14,300	$ -
6	Clean Electrical Power	$ 120,000	$ 146,385	$ 146,385	$ 0
7	Circulating Water Channel	$ 285,000	$ 265,046	$ 256,878	$ 8,168
8	Dynamometer & Emissions Tes	$ 295,000	$ 258,083	$ 251,902	$ 6,181
	Misc. Admin	$ -	$ 481	$ 699	$ (218)
				$ -	
9*	Research - Energy Harvester		$ 65,500	$ 6,769	$ 58,731
10**	Material Testing Equipment		$ 212,087	$ 251,285	$ (39,198)
			$ -	$ -	
11***	Structural Test Bed Upgrade		$ 84,070	$ 54,070	$ 30,000
12***	Duel Fuel Test Bed		$ 65,000	$ 66,726	$ (1,726)
13****	3D printer		$ 95,000	$ 110,719	$ (15,719)
14*****	CFD Workstations			$ 28,269	$ (28,269)
				$ -	
	Labor		$ 104,847	$ 119,910	$ (15,063)
	Fringe 30 %		$ 31,454	$ 35,152	$ (3,698)
	Overhead (labor only) 35%		$ 36,696	$ 41,969	$ (5,273)
	Total	**$ 1,920,000**	**$ 1,985,509**	**$ 1,987,879**	**$ (2,370)**

* additional funding awarded 6/8/2011

** re-alignment of spending approved 3/9/2012

*** re-alignment of spending requested 5/13/2013

**** re-alignment of spending requested 9/23/2014

***** Purchase verbally approved 9/1/2015

During the life of the project there were three no-cost extensions granted. The reason for the extensions was largely due to vendor delays and/or failure to respond to requests for bid. Some of the delay was due to realignment of priorities and evaluation of how best to utilize the funds.

Table 1 (next page) shows the spending vs the last approved budget from September 2014. Verbal approval was given in September 2015 to purchase two multi-processor CFD workstations (item 14). As a full budget update was not provided at that time, the spending comparison is give relative to the last fully approved budget.

Wavemaker

Edinburgh Designs, Ltd. was selected as the supplier for the new eight-paddle wavemaker (Figure 1). Edinburgh, is the supplier for the new wavemaker in the Maneuvering and Seakeeping Basin (MASK) in Carderock. The PI has experience using a similar (eight-paddle wavemaker) at University College London. Technicians from Edinburgh Designs, Ltd, traveled to Webb Institute to install and commission the equipment. Final commissioning for the wavemaker was completed in May 2011. The OCEAN software provides the capability to produce the following irregular spectra: Peirson-Moskowitz, Bretschneider, JONSWAP, Gaussian, and Neuman. Additionally the software enables the system to vary phase angles temporally and spatially. Finally the system uses force-feedback control for active wave damping.

Figure 1: Eight-paddle wavemaker installed

Three Webb Senior Theses have utilized the new wave making capabilities. The first thesis investigated ride control for planing craft, (Morgan, J. C., Walker, N. I., and Walling, R. J. 2012 "Planing craft ride control using a neural network," Webb Institute, Glen Cove, NY). This project resulted in a working test platform that will be refined in future work. This effort was partially supported by the Atlantic Center for Innovative Design and Control of Small Ships (ACCeSS). ACCeSS is funded by ONR contract number N00014-10-1-0652. The second thesis made comparative studies between AXE bow and X bow hull forms (Soja, J. and Waterhouse, S. 2013 "A performance comparison of the AXE and wave-piercing bow applied to offshore supply vessels," Webb Institute, Glen Cove, NY). The final thesis compared a Webb designed catamaran with the Southampton catamaran hull form (Zangle, T, 2013 "A seakeeping analysis of the semi-elliptical hull catamaran," Webb Institute, Glen Cove, NY).

Purchases on the completed project total $137,965.

Carriage/Double Rail

Webb has relied on a single overhead rail since it first built the Robinson Model Basin in 1946. The single rail configuration has some limitations, particularly when large side-forces are involved, or if large (bulky) equipment must be carried along with the model. After investigating configurations at other tanks, Webb selected a linear guide as the best solution. Both the support system and Thomson linear rail has been procured. Delayed delivery of the Thomson linear guide (SRA116SS SM x 978") has resulted in a shift of the installation. The linear guide will be

installed in the spring at no additional cost to ONR (as agreed upon by the support vendor). A section of the linear guide can be seen in Figure 2 below.

Timing of the project was such that Webb did not procure a new carriage. The design for the carriage is nearly complete, however Webb identify separate funding for the new carriage.

Figure 2: Thomson linear guide with stainless steel, 1.0 inch diameter rail.

Purchases for this project total $17,569.

PMM and MDOF Dynamometer

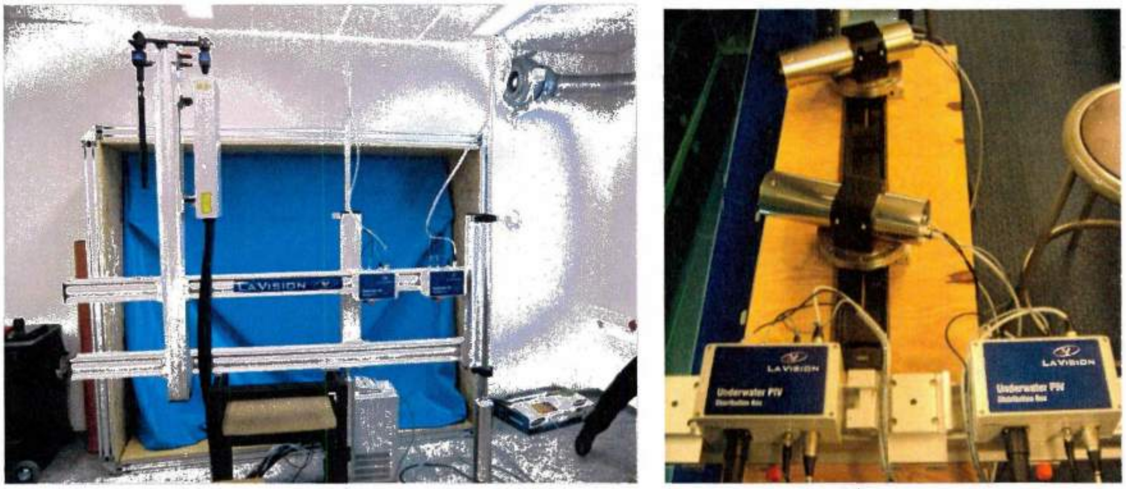
Early in this project it was determined that Webb would not seek to procure a planar motion mechanism (PMM). Webb did not have an immediate need for this device and shifted its priorities to other purchases.

The need for multiple degree of freedom (MDOF) is common for Webb towing tank projects. After discussions with Stevens Institute, it was decided that Webb would procure two ATI Automation 6 DOF transducers (IP68 Mini40 Transducer Radial exit). The two units have multiple range settings (5-10 lbf, 10-20 lbf, and 20-40 lbf). These units are battery operated, supporting our thrust toward a wireless system on the towing carriage.

Purchases for this project total $19,531

Particle Image Velocimetry

LaVision, Inc. of Ypsilanti, Michigan, was identified as the supplier of the new particle image velocimetry equipment. LaVision is a leader in particle image velocimetry technology (PIV) and was the supplier for Stevens Institute's PIV system. The system that was purchased is capable of operating in air and in water. This configuration gives Webb the flexibility to use this equipment with our Circulating Water Channel or in the Robinson Model Basin. Two configurations of the system can be seen in Figure 3a and Figure 3b below.



(a) (b)

Figure 3: LaVision PIV system – (a): underwater config, (b): open air config.

The equipment arrived on campus in April 2012. During July 2012 the system was commissioned by LaVision personnel. Initial training on the set-up, operation, and post-processing was completed at that time. Training for the equipment was completed at LaVision's facilities in Ypsilanti, Michigan.

The purchases for this project total $208,910.

Data Acquisition System

As part of this project, Webb sought to improve the instrumentation in the Robison Model Basin and the Circulating Water Channel. The larger items include wireless telemetry, eddy current sensors, laser displacement units, velocity sensors for the water channel, velocity profiler for the towing tank, and laser scanner for field work.

The wireless system was procured from National Instruments and includes a chassis with four slots for various signal conditioners (NI CDAQ-9184), a wireless access point (MOXA AWK-3121), a four channel dynamic signal acquisition module for accelerometers (NI 9234), an eight channel high-speed analog module for wave probes or force blocks (NI 9221), and a four channel analog bridge input module (NI 9237). This mix of modules covers all of Webb's current instruments.

Webb's Hydronautics force blocks require specific cores that are no longer available from the manufacturer, however, the force blocks themselves are in perfect working order. We determined that eddy current sensors can be used instead of the magnetic reluctance cores that have been used in the past. The Micro-Epsilon U3 sensors and DT 3010-A signal conditions were purchased. The eddy current sensors have a different size than the Hydronautics cores, so inserts were made using the 3D printer.

The trim and heave measurements used to be made using an RVDT and LVDT, respectively. These required calibration each time the system was used. Based on information from the University College London towing tank, Webb procured two Micro-Epsilon optoNCDT 1302 laser displacement instruments. This eliminates the need for calibration each time the tank is used.

In the past, Webb relied exclusively on Pitot tubes for velocity measurements in the Circulating Water Channel. In an attempt to improve the precision and accuracy of the velocity measurements, several devices were considered. The Nortek Vectrino was deemed the best choice, so two of these probes were purchased. The devices are compatible with both the water channel and towing tank data capture.

To enhance the instrumentation in the towing tank, a Nortek Signature velocity profiler was purchased. This type of unit has been used at the David Taylor Model Basin, and was recommended as a quick alternative to setting up the PIV system. The PIV system is more appropriate for investigating a wide domain, while this instrument provides a narrow domain.

Webb also upgraded its video data capture equipment. This included a 32 inch HD monitor, two wireless cameras, data storage, database management software, and character bar for trial identification. This integrated system was provided by Creative Business Technologies of Sea Cliff, NY.

The last data acquisition item procured is a laser scanner. It will be used to scan vessels, creating a 3D image of the vessel for hydrodynamic or structural analysis. The FARO Focus 3D-X130 generates a 360 degree 3D image. It has resolution down to 2 mm over a 130 meter range. This device will be used to aid in a study on sallying constants for small craft.

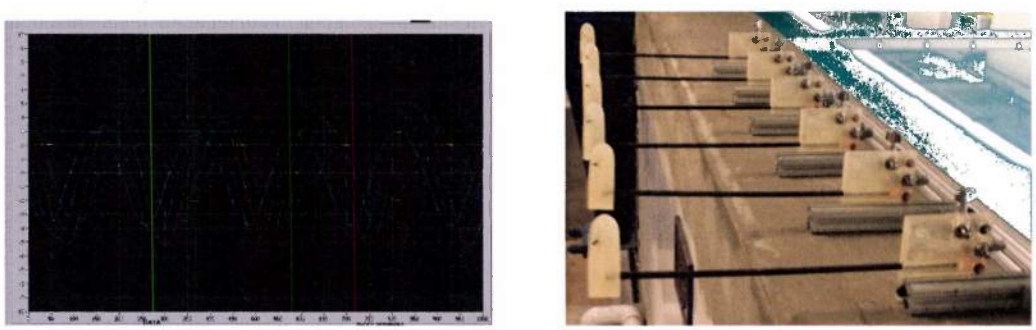
Purchases for this project total $134,036.

Wave Probes

Webb has traditionally constructed its own wave probes with good success, however some have questioned the accuracy of these probes relative to those that are commercially available. To address this issue, Webb has procured two additions to our wave probe instrumentation. The first involves a new eight-probe wave gage controller from Edinburgh Designs. This controller uses our existing hardware but provides integrated circuitry that eliminates cross talk between multiple probes. Figure 4a shows a sample time history, while Figure 4b shows six in-house probes in an array. This system is being used for an ongoing ONR Grant N00014-14-1-0606 (Partially Ventilated Transom Flow Elevations – Unsteady Analysis).

The second system purchased is an eight-probe ultrasonic system from General Acoustics (UltraLab ULS HF108). This system is capable of measuring wave slopes up to breaking, a feature not common among most ultrasonic systems. The probes are synchronized to avoid cross-talk, and can be configured for low (eight probes) or high (four sets of two) wave slopes.

Purchases for this project total $40,247.



(a) (b)

Figure 4: (a): Wave probe signals, (b): Eight in-house wave probes.

Beach

The prior beach for Robinson Model Basin was inadequate for our new wave-making capabilities. Edinburgh Designs, Ltd. provided guidance regarding towing tank beach designs. Based on the Edinburgh Designs information, Webb designed and built a new beach with a parabolic profile and seven-degree slope at the waterline (see Figure 5). Parts were cut in-house using Webb's ShopBOT CNC router.

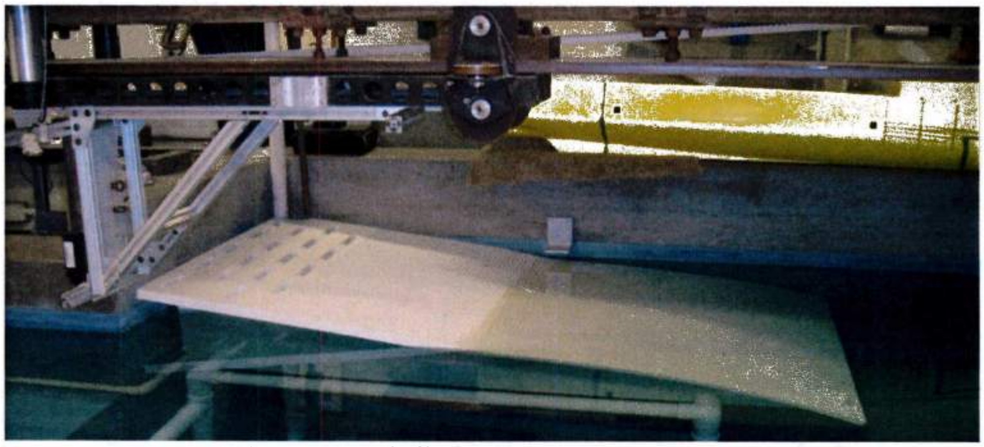


Figure 5: Parabolic Beach – photo shows one side of tank

Purchases for the new beach total $760.

Underwater Viewing Window

In order to provide better visualization for experiments, a viewing window was installed in the towing tank. A civil engineering firm, Dvirka and Bartilucci Consulting Engineers, was retained to perform a feasibility analysis and to design the cutout and viewing pit. Reynolds Polymer Technology, Inc was selected to fabricate the window, and American Sealants installed the window. This project was completed in March 2012 (see Figure 6).

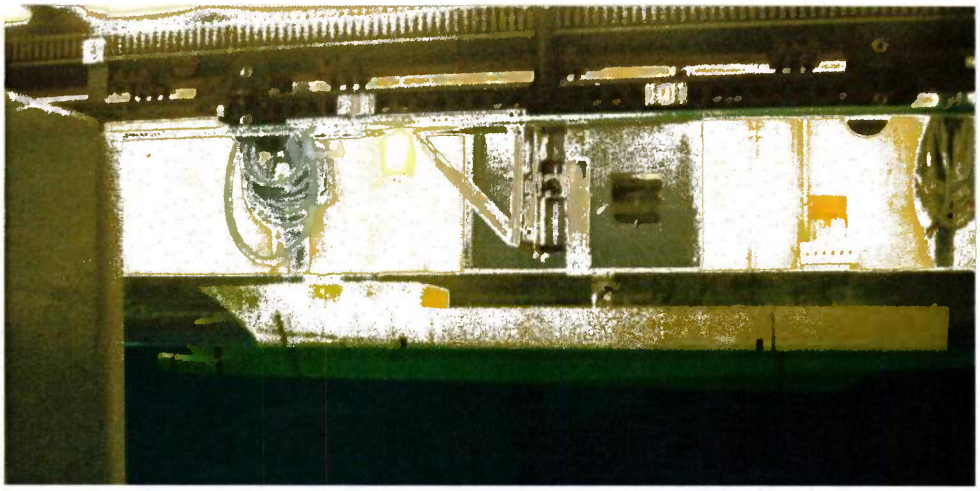


Figure 6: Tank viewing window – stationary model in background

Purchases for this project total $26,126.

Carriage Speed Control

Testing in the Webb towing tank has traditional involved small, low mass systems and our drive motor and controller were sized accordingly. Webb now regularly conducts propeller tests in the towing tank and the mass of the propeller boat system is close to the maximum of the existing system. As such, Webb decided to upgrade the carriage motor and motor controller to accommodate increased torque with better inertia matching. The new system includes a Parker Compax3 T10 servo drive and a Parker MPJ1426 high inertia servo motor. This combination will allow smoother operation of the drive system under "large" loads, as well as increasing the top speed from 17 ft/sec to roughly 20 ft/second.

Purchases for this project total $9,967

Tank Environmental

This project was intended to clean up hanging wiring, suspended piping and provide some air-conditioning to the tank and attached electrical laboratory. After some reprioritization, this project was reduced to simply providing air conditioning to the electrical laboratory and wiring for the new 3D printer.

Purchases for this project total $7,736

Raise Sill

In March of 2011, it was decided that the raised sill for the towing tank would be eliminated from the overall project plans. However, with the commissioning of the new eight-paddle wavemaker, it became evident that some increase in the sill height was warranted. A significantly reduced project was undertaken in August 2011 to raise the sill by five inches (Figure 7).

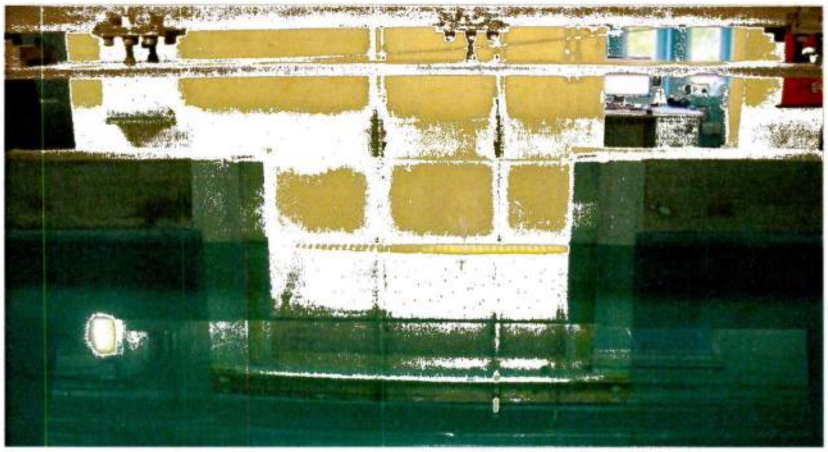


Figure 7: Raised tank sill (grey paint)

Purchases for this project total $14,300.

Clean Electrical Power

Prior to undertaking this project, the quality of the electrical service to two different laboratories was corrupted by large equipment on the line, including HVAC systems, student entertainment systems, and assorted appliances. An electrical engineering consulting firm (Cameron Engineering and Associates, LLP) was retained for this project. The engineering firm surveyed both facilities and developed plans for the improvements. The dedicated service provides power conditioning to remove any harmonics and to provide an un-interrupted power supply in Robinson Model Basin and three-phase 480-volt service to Haeberle Laboratory. This improvement has resulted in improved signal-to-noise ratios of our instrumentation and has significantly improved the fidelity of the data collected during experimentation.

Purchases on the completed project total $146,385.

Circulating Water Channel

Edinburgh Designs, Ltd. was selected as the supplier for the new circulating water channel. Edinburgh Designs has a reputation for providing high quality, turn-key water channels and flumes. The new equipment has a variable speed AC drive that provides improved control of the fluid velocities. Two Edinburgh Design technicians installed and commissioned the new circulating water channel in August 2011 (Figure 8). The working platform behind the channel has been installed, and computer and data acquisition equipment are in place.

Currently we are making modifications to the expansion chamber to limit the air/water mixing that is occurring. We have fabricated inserts for the expansion/stilling region of the channel in order to reduce the angle of expansion upon exiting the test section. The inserts have been machined and will be installed sometime in October.

Figure 8: Circulating water channel with platform and instrumentation

Three Webb Senior theses have used the new equipment to investigate air layer drag reductions. The first effort investigated drag reductions on deadrise surfaces (Hagan, N. T., and Oczeretko, J., 2012 "Air layer drag reduction applied to flat-plate resistance testing," Webb Institute, Glen Cove, NY). The findings of that effort are uncertain largely due to the design of the test apparatus. This effort was partially supported by the Naval Engineering Education Center (NEEC). NEEC is funded by NAVSEA contract number N65540-10-C-0003. The second thesis sought to improve the design of the test apparatus (Murphy, S. and Spillane, C. 2013 "The effect of air lubrication on a flat plate at varying angles of trim with regard to drag reduction," Webb Institute, Glen Cove, NY). The results of this effort were also uncertain, however the substantial improvements were made to the test apparatus. The third thesis investigated Coanda effect on the trailing edge of a typical yacht keel foil section (Granger, S. M. and Neureuter, R. P. 2014 "A comparative analysis of low-aspect-ratio conventional and single-slotted circulation control foils intended for marine hydrodynamic applications." Webb Institute, Glen Cove, NY). In that effort, the Coanda foil was able to generate more lift at zero degrees angle of attack than the conventional foil at eight degrees angle of attack. This increase in lift is believed to be limited to low speed forward velocity of the foil.

Modifications to the expansion chamber to limit the air/water mixing have been successful. Inserts were fabricated for the expansion/stilling region of the channel in order to reduce the angle of expansion upon exiting the test section.

Purchases on this project total $256,878.

Dynamometer and Emissions Testing

Webb Institute has maintained a marine engineering laboratory since it moved to Glen Cove, NY, in 1946. The laboratory includes a steam plant, APU (air power unit – turbine), and five diesel engines of varying sizes. Prior to this project Webb had antiquated means for testing engine outputs and no emissions testing. In upgrading this facility Professor Neil Gallagher has purchased and installed a number of pieces of equipment. To date, the list of purchased and installed equipment includes the following:

1. Semtech DS portable emissions analyzer, which can be used on two 120 hp Cummins diesel engines and on a 700 hp Detroit Diesel Series 60 engine (Figure 9a).
2. Midwest Dynamometer eddy current dynamometer power unit for the two Cummins engines.
3. Go Power water-brake dynamometer on the Detroit Diesel engine (Figure 9b).

Several projects have been completed using the newly acquired emissions testing equipment. The first effort involved establishing the baseline performance of the Cummins engine. Using conventional diesel fuel, a record of emissions under a range of speeds and powers was made for future comparisons.

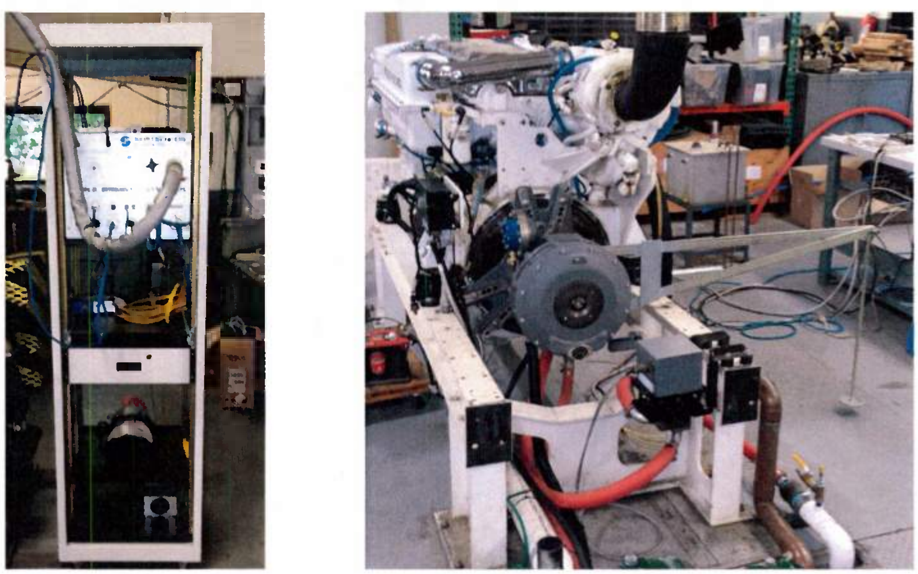
Three Webb Senior Theses have utilized this equipment. The first thesis (DelGatto, N. J., Manis, K. R., and Talarico, R. J., 2012 "The production of algae biodiesel for comparative engine emissions testing," Webb Institute, Glen Cove, NY) created four types of biodiesel fuel and ran them in one of the Cummins engine. The engine power with each fuel was measured and recorded using the eddy current dynamometer equipment, and the emissions produced by each fuel were measured and recorded using the emissions analyzer. These were compared to the baseline measurements, looking for improvements in power and emissions.

The second Senior Thesis, (Lum, A., 2012 "An emissions analysis of a fuel-emulsion system on a four-stroke four-cylinder diesel engine," Webb Institute, Glen Cove, NY), investigated two emulsions, one with water in diesel fuel, and one with ethanol in diesel fuel. Both emulsions were created and run in the Cummins engine. The engine performance, both with regards to power and emissions, with each emulsion was recorded and compared to the baseline measurements, looking for power and emissions improvements.

The third Senior Thesis (DeMarco, R., 2013 "Applying Molecular Cracking to Marine Diesel Engines," Webb Institute, Glen Cove, NY) tested a device in which heat rejected to the cooling water is used with a catalyst to crack the hydrocarbon chains in fuel oil into lighter fractions, thus promoting more complete combustion. The devise was provided by its manufacturer and installed on the Cummins engine. The fuel consumption and emissions were measured before the device was installed and then again with the device under a variety of cooling water flows and temperatures. No clear trend was observed; in some conditions reduced emissions and improved fuel consumption we observed, in others the opposite was noted. The manufacturer states that the device was tested on an older mechanical engine while the device was intended to be used on a newer electronic engine.

Procurements and installation is nearly complete for the water-brake dynamometer. Remaining purchases and integration include fuel flow meters, and torque instrumentation necessary to connect to the Semtech emissions analyzer. This project should be completed by the end of 2014.

Purchases on this project to date total $251,902.



(a) (b)

Figure 9: (a): Semtech DS Emissions Analyzer (b): Go Power water-brake dynamometer.

Research - Energy Harvester

This project was intended to conduct research on a novel slow-moving current energy harvester. Some level of literature search was completed, however the effort was redirected toward support of two ongoing research projects. Specifically, the cost show are for travel related to those projects: Partially Ventilated Transom Flow Elevations (N00014-13-1-0803), and the follow on project Partially Ventilated Transom Flow Elevations – Unsteady (N00014-14-1-0606). The former is complete while the latter is ongoing.

It has been suggested that the Energy Harvester project be resubmitted for funding now that the capabilities of the Circulating Water Channel have been improved and that the 3D printer is operational.

Purchases for this project total $6,769.

Materials Testing Equipment

Many of the vessels built today incorporate composite structures. As such, Webb sought to improve our research capabilities in this area. In March 2012 a request was made to allow for the purchase of modern materials testing equipment. The purchase of that equipment was achieved within the constraints of the original budget. Based on a re-alignment of funds, the Program Manager approved the purchase and installation of an Instron 8801 materials testing system (see Figure 10). The system includes the following capabilities: tension, compression, fatigue, and three-point bending. It also includes an environmental chamber that enables testing materials over a range of temperatures (-150C - +350C).

Additional purchases were made for this system in 2015. These include and optical extensometer, control card for the environment chamber, and hydraulic grips for tensile and fatigue testing. It should be noted that the optical extensometer is compatible with our Southward Emery universal test machine (see next section).

During the 2014-2015 academic year, a senior thesis (Chen, M. J. J. and Owen, C. C., 2015 "Strength testing of shipboard materials at various temperatures," Webb Institute, Glen Cove, NY) made use of this equipment. The students investigated the tensile strength of specimens from the mobile offshore drill ship *Kulluk*. The Kulluk was operated in the artic before running aground in 2012. The specimens were tested in temperatures ranging from -80C to +150C. The American Bureau of Shipping (ABS) supported this effort through the purchase of the 60 specimens used in this thesis. Metal Shark boats also provided aluminum specimens to be tested over the same range of temperatures.

Figure 10: Instron 8801 materials testing equipment (environmental chamber not shown)

Purchases for this project total $251,285.

Structural Test Bed Upgrade (Universal Testing Equipment)

Part of Webb's structural test equipment includes a Baldwin-Southwark universal test fixture that was outdated and lacked digital recording of the loads and elongations applied to the test piece. This frame is capable of applying loads up to 200,000 pounds. In order to support the refurbishment/upgrade of this equipment, Webb proposed a realignment of funds such that one original project was eliminated, and budgets for remaining projects were reduced. This realignment was approved by the program officer roughly in June 2013

The equipment was received in July 2013 and the process of commissioning the equipment began in September 2013 (see Figure 11). During the first effort to commission the frame, there was an issue with the one of the limit switches and the unit would not hold a load. In May of 2014, Instron was able to overcome the limit switch issue and certified the equipment to be capable of applying loads between 2,000 and 200,000 pounds. Training for this equipment was completed in September 2014 and the equipment is ready for use.

An additional purchase of an expansion module for data capture added 4 additional channels, along with two strain gauge adapters, panel grips, and a USB camera for synchronized video capture.

During the 2014-2015 academic year, a senior thesis (Gilfus, Z. J. and Kuczera, S. F., 2015 "An analysis of stiffened aluminum panels under tension, using mechanical testing and finite element analysis," Webb Institute, Glen Cove, NY) made use of this equipment, investigating tensile strength of welded aluminum panels. Metal Shark Boats, again, provided the necessary test panels for this effort. The optical extensometer was not yet available for use on this project.

Purchases for this project total $54,070.

Figure 11: Instron IP-XH Universal testing equipment upgrade.

Dual Fuel Test Bed

With ongoing development of duel fuel engines for the marine market, Webb proposed a realignment of funds to include the purchase of a Duel Fuel Testing system. The realignment request was approved in May of 2013. A Webb Senior Thesis was involved in the development of the new duel fuel system (Thompson, A. and Wingfield, E., 2015 "Analysis of Natural Gas as Fuel for an Electronically-Timed High-Speed Diesel Engine", Webb Institute, Glen Cove, NY). This thesis involved procuring and installing a dual fuel system on the engine. A CNG tank and the appropriate connections were included after it was discovered that the municipal gas supply was insufficient to power the engine at full load. As a part of this effort the Detroit Diesel Series 60 Marine engine was run under load and a baseline set of emissions were measured using the Semtech DS Emission Analyzer.

A BRC FuelMaker FMQ2 refueling appliance was procured in order to provide high pressure fuel. The FMQ2 unit takes low-pressure natural gas from the municipal supply and fills the CNG tank to a pressure of 3,600 psi. The tank then supplies the gas to the engine, at which point a Parker FM 80 pressure regulating valve reduces the gas to 60 psi for entry to the dual fuel system. That system, a Continental Controls Corporation Gas Substitution System (GSS) injects low pressure gas into the supply air to the cylinders. In addition this unit interfaces with the engine's electronic controls to regulate the amount of gas substituted for diesel oil. Up to 70% of the engine fuel can be supplied as gas. Completion of the installation is expected in the spring of 2016, followed by testing for both performance and emissions under dual fuel operation.

A Yanmar 4JH110, a four-cylinder four-stroke marine engine rated at 80 kW (110 hp) was also procured as a part of this project. This engine is a fully electronic common rail engine, and will replace a Cummins 4B3.9TA engine currently used as a part of the emissions testing. The Cummins engine is a traditional mechanically injected engine, and though it has been used in several alternate fuel projects, the common-rail Yanmar will be a much better test engine. A power take-off (PTO) clutch has been included with the engine to allow connection to Webb's eddy current dynamometer.

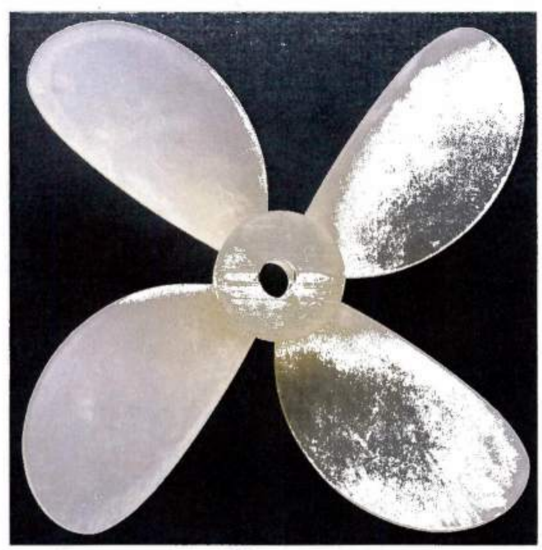
Purchases for the duel fuel system total $66,726.

3D Printer

During the course of this project, research projects at Webb required that we purchase either stereo lithographic parts, or parts generated from a 3D printer. Webb then once again reprioritized its spending to include a 3D printer. We sought quotes and prototypes from 3D Systems and Stratasys (the two dominant manufacturers in the price range of interest). Webb found that the 3D Systems ProJet HD 3500 Max provided enhanced capabilities over the Stratasys Objet 30. Additionally, the ProJet part tolerances were closer to the actual drawing. Lastly, the wax support system used by the ProJet allows us to create captured parts (moving parts within other parts).

The reseller (CAD BLU) provided additional supplies and convection oven as incentive to purchase from them. The installed unit can be seen in Figure 12a and an eight inch propeller that built with the ProJet and tested in Robinson Model Basin can be seen in Figure 12b. Webb has utilized the new 3D printer in one senior thesis (Hanford, A. M. 2015 "An Investigation of the Effects of a Hydrofoil on Seakeeping Performance of the Semi-Elliptical Catamaran," Webb Institute, Glen Cove, NY), as well as to create parts for our in-house wave probes. This equipment will be used to create vane wheels for wake evaluation behind a model of the *USS Monitor* in the coming year.

(a)



(b)

Figure 12: (a): ProJet 350 HD Max, (b): Eight inch 3D printed propeller.

Purchases for this project total $110,719

CFD Workstations

Toward the end of the project, Webb requested, and was granted, approval to purchase three CFD workstations. As the funds for the project were nearly consumed, only two workstations could be purchased. This purchase exceeded the grant funding. Webb Institute contributed $2,370 so that we could purchase the two machines. The workstations are Dell Precision Tower 7910, with 28 cores in each machine. These workstations will be used to run CFD (Star CCM+) and FEM (Multiphysics/NASTRAN).

Purchases for this project total $28,629.

Labor/Fringe/Overhead

The labor shown represents costs incurred by Webb in support of this project. It includes labor for demolition, site preparation, administrative, fabrication, and research. The inclusion of labor/fringe/overhead was approved in March of 2011.

NOTE: Overhead was only applied to the labor cost as per the March 2011 agreement.

Labor/Fringe/Overhead total $197,031